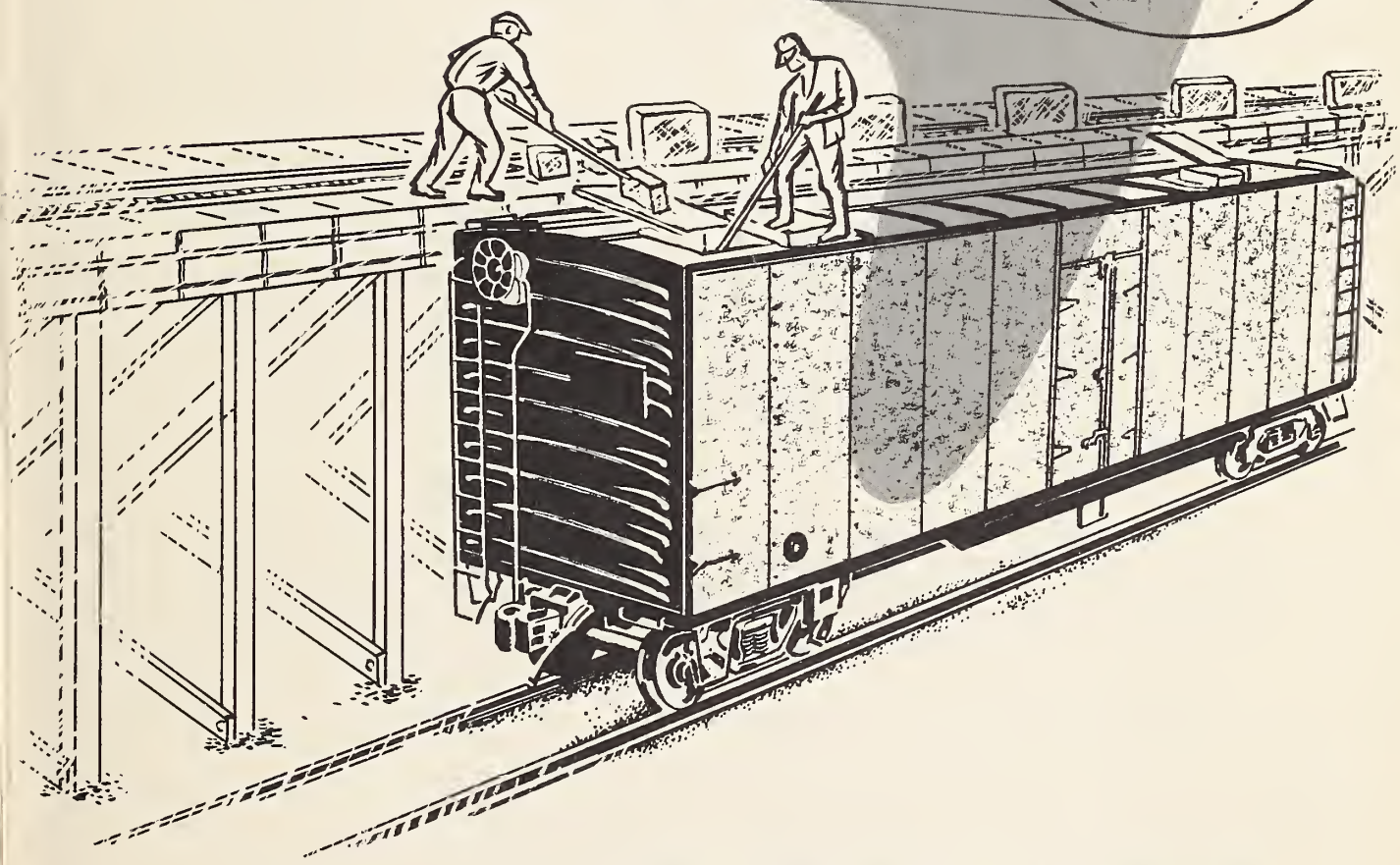
RAIL TRANSIT REFRIGERATION OF MATURE-GREEN TOMATOES from the Lower Rio Grande Valley of Texas



UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division

Agriculture – Washington
AMS – 188

ACKNOWLEDGMENTS

The cooperation and help of the following are gratefully acknowledged:

For furnishing test cars originating in the Rio Grande Valley and recovering thermometers at destinations--

Atlantic & Pacific Tea Company
Easwest Produce Company
Pacific Fruit & Produce Company
Ben Goldberg Company

For furnishing icing records and making requested bunker inspections--

American Refrigerator Transit Company
Chicago, Rock Island & Pacific Railroad
Fort Worth & Denver Railway Company
Fruit Growers Express Company
Pacific Fruit Express Company
Missouri Pacific Lines

For assistance in the return through Customs of thermometers from Canadian destinations--

Austin E. Anson, Texas Citrus & Vegetable Growers & Shippers

For invaluable assistance at loading and destination points, the following coworkers in the U. S. Department of Agriculture:

W. R. Buford, B. A. Friedman, G. B. Ramsey, W. A. Radspinner (Formerly employed), M. A. Smith, and W. R. Wright.

June 1957

Transit Refrigeration of Mature-Green Tomatoes Shipped by Rail from the Lower Rio Grande Valley of Texas

H. B. Johnson and D. W. Newsom

Agricultural Marketing Service
Biological Sciences Branch
Quality Maintenance & Improvement Section
Harlingen, Tex.

During the spring season the movement of mature-green tomatoes from the Lower Rio Grande Valley totals more than 2,500 rail cars. The kind of protective services to use for this important commodity is a controversial subject among Texas shippers.

The ideal temperature range for mature-green tomatoes in transit is 55° to 65° F. Such temperatures allow moderate ripening and also afford protection against high temperature rots such as bacterial soft rot and rhizopus rot. Exposure to temperatures below 50° adversely affects the ripening performance of tomatoes and increases alternaria rot in the ripening room. One cause of chilling injury is over-refrigeration in transit. Chilling injury is most likely to occur in shipments which have been diverted or held on the track under heavy icing for a number of days before unloading. A combination of field chilling and refrigeration in transit sometimes results in chilling injury in shipments from fall and winter producing areas. However, field chilling temperatures are rarely encountered in spring grown Texas tomatoes.

A study has been made to develop an icing schedule, adapted for south Texas conditions, which will provide transit temperatures within the desired 55° to 65° F. range. Results from shipping tests during the past several years show that standard refrigeration service without ventilation gives undesirably low temperatures, and that the practice of using standard refrigeration in combination with a ventilating service produces erratic results. Under standard refrigeration the bunkers are filled to capacity at each regular icing station, usually about every 24 hours. Modified icing Rule 247 with 1 or 2 reicings to capacity, and vents closed to destination, provides lower temperatures than are desirable.[1] However, with further modifications, this icing rule appears to provide satisfactory refrigeration for mature-green tomatoes moving from the Lower Rio Grande Valley.

Estimation of Ice Requirement

In cooling a carload of tomatoes it is necessary to remove (1) field (sensible) heat from the fruit, boxes, and car structure; (2) the vital heat, or heat of respiration of the product; and (3) the heat leakage into the car when the outside temperature is greater than that inside the car. Estimates of the amounts of heat from these sources for a closed carload of 700 lugs of tomatoes and the ice meltage required to absorb this are as follows:

Source of heat to be removed	Amount	Ice requirement
Sensible heat:		
Fruits (23,000 lbs.; specific heat = .95)	21,850 B.t.u.	152 lbs./degree cooled
Lugs and strips (3,500 lbs.; specific heat = .33)	1,155 "	8 " " "
Car interior (8,820 lbs.; specific heat = .33)	2,910 "	20 " " "

[1] Rule 247 (National Perishable Freight Committee Perishable Protective Tariff 17) calls for initial icing, with 1 or 2 reicings in transit.

Source of heat to be removed	Amount	Ice requirement
Vital heat:		
At 90° F. (11.5 tons x 10,384 B.t.u./ton/day)	119,416 B.t.u.	829 lbs./day
At 80° F. (11.5 tons x 9,394 B.t.u./ton/day)	108,031 "	750 " "
At 70° F. (11.5 tons x 7,634 B.t.u./ton/day)	87,791 "	610 " "
At 60° F. (11.5 tons x 4,488 B.t.u./ton/day)	51,612 "	358 " "
At 50° F. (11.5 tons x 3,300 B.t.u./ton/day)	37,950 "	264 " "
Leakage through fan car structure (80° F. Mean outside temperature)		[1] 2,000 " "

[1] This figure is based on actual ice meltage for a number of test cars and takes into consideration heat leakage into the car and heat developed from operating the fans.

For example, a closed car of tomatoes, with fans operating, cooling 25 degrees from an initial temperature of 80° F. to a temperature of 55° during a 3-day period, with an 80° daily mean outside temperature, will require the following amount of ice:

Source of heat	Ice required (pounds)
Sensible heat	
Tomatoes (152 x 25)	3,800
Boxes and bracing (8 x 25)	200
Car interior (20 x 25)	500
Vital heat	
First day	643
Second day	358
Third day	311
Leakage from car	6,000
Total	11,812

The calculations for vital heat are based on the loading temperature of the tomatoes for the first 6 hours of the first day and for the remaining 18 hours are based on the average temperature to which the load had cooled. For the second and third days, calculations are based on the average temperature to which the load had cooled. These calculations assume that the load is to be cooled to 55° F. and that a mean outside temperature of 80° is encountered during the first 3 days of transit. The assumption is also taken that ventilators are closed and fans are in operation. Ice requirement for the first 3 days for shipments of tomatoes with different loading temperatures are shown below.

Loading temperature of fruit	Ice requirement
80° F.	11,812 lbs.
85° F.	12,733 "
90° F.	13,839 "

A large amount of ice is required during the first 3 days in order to reduce the load temperature to the desired level. After the temperature is lowered to 55° F. the ice requirement for maintaining this temperature is relatively low. The heat evolved by respiration of the tomatoes at 55° will melt only 311 pounds of ice per day. Assuming that after the first 3 days of transit the mean outside temperature has dropped to 70° heat, leakage into a refrigerator car with fans operating will melt about 1,500 pounds of ice per day. In order to maintain the load temperature at 55° under these conditions approximately 1,800 pounds of ice will be melted daily. By the time the amount of ice added at the initial and first reicing is melted, the load temperatures are in the desired range. This point is usually reached after 72 hours in transit. The addition of ice at this time would result in cooling some of the tomatoes below the desired range. For this reason the schedule provides for running without ice for approximately 36 hours. During this period the coldest part of the load may warm 5 to 6 degrees while the warmest part shows little or no warming.

Test Cars

Transit temperature data were collected from a large number of tomato cars during the course of this study, but only the data from 8 of those cars are presented in this report. These 8 cars were selected to compare icing and ventilation services commonly used in this area with a modified icing service calculated on the basis of the amount of ice required to cool a load of mature-green tomatoes to 55° F. Five of these cars moved under customary icing and ventilation services. The remaining 3 moved under a modified icing service developed for transit of mature-green tomatoes from the Lower Rio Grande Valley.

The cars used in these tests were standard 40-foot, end-bunker refrigerators. All were equipped with fans except car 1. The car designation, kind of protective services, loading temperatures, and related information are given in table 1.

Loading

Six of the test cars were loaded with 700 standard 33-pound lug boxes placed solid (no center brace), crosswise of the car; car 5 was loaded with 366 wirebound 60-pound boxes, and car 6 with 399 wirebound 60-pound boxes. Average loading temperatures of the tomatoes varied from 83° to 92° F. for the different cars.

Commodity Temperatures

Two recording thermometers were placed in the center of a lug or wirebound box of tomatoes in each of the test cars, one in the bottom layer centerline next to a bunker and the other in the top layer centerline in the doorway stack. The centerline position in these two locations is representative of the coldest and warmest parts of the load. The air temperatures recorded within the lug or wirebound boxes so closely approximated the tomato temperatures that they are referred to as "tomato temperatures" in this report. Tomato temperatures were taken with hand thermometers during loading and unloading to supplement the data from the recording thermometers. Transit temperatures obtained by means of the recording thermometers and plotted at 6 hour intervals are shown in figures 1 through 8.

Icing and Ventilation

The protective services for the different cars are given in table 1.

All except cars 2 and 3 moved with vents closed to destination. Car 2 moved with vents closed to Portal, N. Dak., and with standard ventilation beyond; car 3 moved with diagonal vents open from origin to destination.

Outside air temperatures calculated from weather records obtained from various points through which these cars passed indicated that the prevailing temperatures were generally normal to above normal.

RESULTS

Car 1. This non-fan car was initially iced with 11,000 pounds of ice and moved under Rule 247 with vents closed to Jersey City, N. J. It was reiced at Houston with 7,800 pounds and at Lexa, Ark., with 6,000 pounds. During loading the commodity temperatures averaged 92° F. The tomato temperature in the bottom bunker position dropped to 45° at the end of the third day and was below 50° until the car was unloaded on the eighth day (fig. 1). The fruit temperature in the top of the load never dropped below 68°, and did not drop below 70° until the fifth day. There was a temperature difference of from 25° to 30° between the top doorway and bottom bunker positions throughout the transit period. This is a common occurrence in non-fan cars. Usually the bottom layer gets too cold and the top layer never cools sufficiently.

Car 2. This car moved to Regina, Saskatchewan, under standard refrigeration with fans sealed in the "on" position. Vents were closed to Portal, N. Dak., with standard ventilation beyond. During loading, tomato temperatures averaged 85° F. Fruit temperatures in the load dropped to the desired level at the end of the second day, but with continued reicing the temperature had dropped below 50° at the end of 4 days (fig. 2). Fruit temperatures ranged between 42° and 46° during the remaining 4 days of transit. It is apparent from these temperatures that standard refrigeration results in over-refrigeration of mature-green tomatoes. The operation of fans in this car reduced considerably the temperature difference between the top and bottom layer positions in the load.

Car 3. This car moved to Edmonton, Alberta, under standard refrigeration with fans sealed in the "on" position. Diagonal vents were open from origin to destination. Tomato temperatures averaged 92° F. at loading.

Approximately 60,000 pounds of ice was supplied to this car, and even though diagonal vents were open, the temperature in the bottom of the load dropped below the desired level. Fruit temperatures in the bottom bunker position were below 50° F. for almost 7 days (fig. 3). The top of the load cooled slowly requiring 36 hours to cool to 70°.

Car 4. This car moved under a modified icing service to Tacoma, Wash., and was reiced 4 times in transit (fig. 4). Fans were sealed in the "on" position and vents were closed to destination. Tomato temperatures during loading averaged 86° F. and were reduced to the desired level at the end of 3 days (fig. 4). The addition of 4,000 pounds of ice at Denver on the fourth day was unnecessary as evidenced by the fact that the temperature dropped below 50° after this ice was added. Reicing at Laurel on the sixth day and at Spokane on the seventh day caused the temperatures to continue to drop and the car arrived at destination with temperatures of 40° and 51° in the bottom bunker and top doorway positions, respectively.

Car 5. This car moved to Chicago, Ill., under Rule 247 with one reicing to capacity. Fans were sealed in the "on" position and vents were closed to destination. Fruit temperatures during loading averaged 91° F. Tomato temperatures in this car were satisfactory during the transit period (fig. 5). However, too much ice was added when the car was reiced at Lexa, Ark., on the second day as evidenced by the fact that there was 4,000 pounds of ice remaining in the bunkers on arrival in Chicago. Unloading was delayed 8 days after arrival in Chicago and the receiver kept the bunkers filled with ice. This resulted in fruit temperatures below 40° for several days. Alternaria rot in test boxes during ripening averaged 40 percent.

Car 6. This car was shipped under Rule 247 to Washington, D. C., and was reiced at Lexa, Ark., with 4,500 pounds. Fans were sealed in the "on" position and vents were closed to destination. Tomato temperatures during loading averaged 83° F. The amount of ice supplied to this car was calculated on the basis of the amount of heat to be removed in cooling the load to 55° and maintaining this temperature to destination (fig. 6). An additional 900 pounds was included as a safety factor.

As shown in figure 6 transit temperatures for this car were generally satisfactory although the bottom layer temperature was slightly lower than desirable for a time. On arrival in Washington, D. C., fruit temperatures averaged 53° and 55° in the bottom bunker and top doorway positions, respectively.

Car 7. This car moved under Rule 247 to Calgary, Alberta, and was reiced with 4,500 pounds of ice at Houston on the first day and at the Minnesota transfer point (Minneapolis) on the fifth day. Fans were "on", and vents were closed to destination. Fruit temperatures during loading averaged 85° F. The amount of ice supplied to this car was also calculated on the basis of the amount of heat to be removed in cooling the load to 55°. Fruit temperatures (fig. 7) reached the desired level after about 3 days and were maintained close to the desired range for the remainder of the transit period. The car arrived in Calgary with fruit temperatures of 50° and 59° in the bottom bunker and top doorway positions, respectively.

Car 8. This car moved under Rule 247 to Regina, Saskatchewan, and was reiced at Houston on the first day with 4,500 pounds and at the Minnesota transfer on the fifth day with 3,600 pounds. Fans were sealed in the "on" position, and vents were closed to destination. Tomato temperatures during loading averaged 85° F. The recording thermometer in the top doorway position failed to operate. Fruit temperatures in the bottom bunker centerline position dropped to 59° at the end of one day and never dropped below 51° during the 8-day transit period (fig. 8). The car arrived in Regina with tomato temperatures of 51° and 54° in the bottom bunker and top doorway positions, respectively (table 1).

Icing Schedule

On the basis of these tests an icing schedule has been developed for shipment of mature-green tomatoes from the Lower Rio Grande Valley. This schedule (table 2) utilizes Rule 247 and regulates the amount of ice to be supplied according to the initial fruit temperature and the distance to market.

CONCLUSIONS

Results obtained from shipping mature-green tomatoes from the Lower Rio Grande Valley at intervals throughout the spring shipping season show that the desired temperature range (55° to 65° F.) can be obtained by using fan cars with vents closed using Rule 247 with limited reicing as recommended under table 2. This procedure results in substantial savings in transit refrigeration charges as compared to standard refrigeration, and results in better quality by preventing chilling injury in transit.

Standard refrigeration results in over-refrigeration during transit. Shipping the cars with vents open from origin to destination in combination with standard refrigeration resulted in slow cooling in the top of the load, over-refrigeration in the bottom layer, and considerable wastage of ice.

Fan cars shipped under Rule 247 with vents closed and with limited amounts of ice used in reicing provided more uniform temperatures in the desired temperature range of 55° to 65° F. Reasonably rapid cooling of warm tomatoes is obtained the first 3 days in transit by heavy initial icing. During this period and for short periods following subsequent reicing, the commodity temperatures in the coldest part of the load may fall below the desired minimum 55° temperature. This exposure is of such short duration that no harmful effects have resulted. Shipping tomatoes in cars with vents closed had no ill effects on condition of the fruits on arrival at market or during subsequent ripening. It can be noted in table 1 that the percentage of ripe and turning tomatoes in the cars with modified protective service was not high despite the moderate temperatures maintained.

The use of a non-fan car shipped under Rule 247 with vents closed resulted in over-refrigeration of the bottom part of the load and unsatisfactory cooling in the top.

The amount of ice required to cool a load of tomatoes from a given temperature to 55° F. was calculated, and the icing schedule presented in this report was developed on the basis of these calculations and data obtained from the test cars.

TABLE 1.--Loading Data, protective services, destination, transit period, and arrival condition of tomatoes in test cars

Car designation	Fruit temperature at loading	Initial icing	Total ice	Icing and ventilation services	Destination	Days in transit	Fruit temperature on arrival BB	Fruit temperature on arrival TD	Arrival condition: Ripe and turning	Arrival condition: Decaying
	°F.	Pounds	Pounds				°F.	°F.	Percent	Percent
1[1]	92	11,000	24,700	Rule 247 - Two reicings P.I.V.C.[2]	Jersey City N. J.	5	43	68	82	3
2	85	10,000	32,000	Standard refrigeration P.I.V.C. Portal, N.D., standard ventilation beyond	Regina, Sask.	8	42	45	30	Trace
3	92	10,500	59,700	Standard refrigeration, diagonal vents open	Edmonton, Alberta	10	48	50	40	2.5
4	86	10,500	24,500	Modified icing, four reicings, P.I.V.C.	Tacoma, Wash.	8	40	51	15	-
5[3]	91	10,500	19,500	Rule 247 - One reicing to capacity P.I.V.C.	Chicago, Ill.	4	46	51	55	0
6	83	10,000	14,500	Rule 247 - One reicing P.I.V.C.	Washington, D. C.	5	53	55	11	0
7	85	10,000	19,000	Rule 247 - Two reicings P.I.V.C.	Calgary, Alberta	10	50	59	7	Trace
8	85	10,000	18,100	Rule 247 - Two reicings, P.I.V.C.	Regina, Sask.	8	51	54	30	Trace

[1]Non-fan car.
[2]P.I.V.C. = Plugs in, vents closed.
[3]Held on track 8 days with bunkers full after arrival in Chicago.

TABLE 2.--Icing schedule for mature green tomatoes loaded warm in Lower Rio Grande Valley[1]

Schedule is based on cars with plugs in, vents closed and with fans operating origin to destination. If car is iced before loading increase the amount of ice added at first reicing by 900 pounds.

Fruit Temp. (°F.)	Days in Transit				
	3 to 4	5 to 7	8	9	10
75 to 80	Rule 247-One reicing Initial icing 10,000 lbs. Reice 3rd icing station (Ft. Worth, Texas, Lexa, Ark., Pine Bluff, Ark., or other comparable points) with 1,800 lbs. (11,800)[2]	Same as 3-4 day transit except reice 3rd icing station with 2,700 lbs. (12,700)	Rule 247-Two reicings Initial icing 10,000 lbs. Reice 3rd icing station with 2,700 lbs. Reice 7th icing station (Minnesota Transfer, Minn., Laurel, Mont. or other comparable points) with 1,800 lbs. (14,500)	Same as 8 day transit except reice 7th icing station with 2,700 lbs. (15,400)	Same as 8 day transit except reice 7th icing station with 3,600 lbs. (16,300)
80 to 85	Rule 247-One reicing Initial icing 10,000 lbs. Reice 3rd icing station with 2,700 lbs. (12,700)	Same as 3-4 day transit except reice 3rd icing station with 3,600 lbs. (13,600)	Rule 247-Two reicings Initial icing 10,000 lbs. Reice 3rd icing station with 3,600 lbs. Reice 7th icing station with 1,800 lbs. (15,400)	Same as 8 day transit except reice 7th icing station with 2,700 lbs. (16,300)	Same as 8 day transit except reice 7th icing station with 3,600 lbs. (17,200)
	3 to 5	6 to 7			
85 to 90	Rule 247-One reicing Initial icing 10,000 lbs. Reice 2nd icing station (Hearne, Texas, Houston, Texas or other comparable points) with 3,600 lbs. (13,600)	Rule 247-Two reicings Initial icing 10,000 lbs. Reice 2nd icing station with 3,600 lbs. Reice 6th icing station (Casper, Wyo., Alliance, Nebr., Huntingdon, Pa., or other comparable points) with 1,800 lbs. (15,400)	Same as 6-7 day transit except reice 6th icing station with 2,700 lbs. (16,300)	Same as 6-7 day transit except reice 6th icing station with 3,600 lbs. (17,200)	Same as 6-7 day transit except reice 6th icing station with 4,500 lbs. (18,100)
90 and Above	Rule 247-One reicing Initial icing 10,000 lbs. Reice 2nd icing station with 4,500 lbs. (14,500)	Rule 247-Two reicings Initial icing 10,000 lbs. Reice 2nd icing station with 4,500 lbs. Reice 6th icing station with 1,800 lbs. (16,300)	Same as 6-7 day transit except reice 6th icing station with 2,700 lbs. (17,200)	Same as 6-7 day transit except reice 6th icing station with 3,600 lbs. (18,100)	Same as 6-7 day transit except reice 6th icing station with 4,500 lbs. (19,000)

[1]The initial icing is limited to 10,000 pounds in order to compensate for cars of different bunker capacities.
[2]Figures in parenthesis indicate total pounds of ice added.

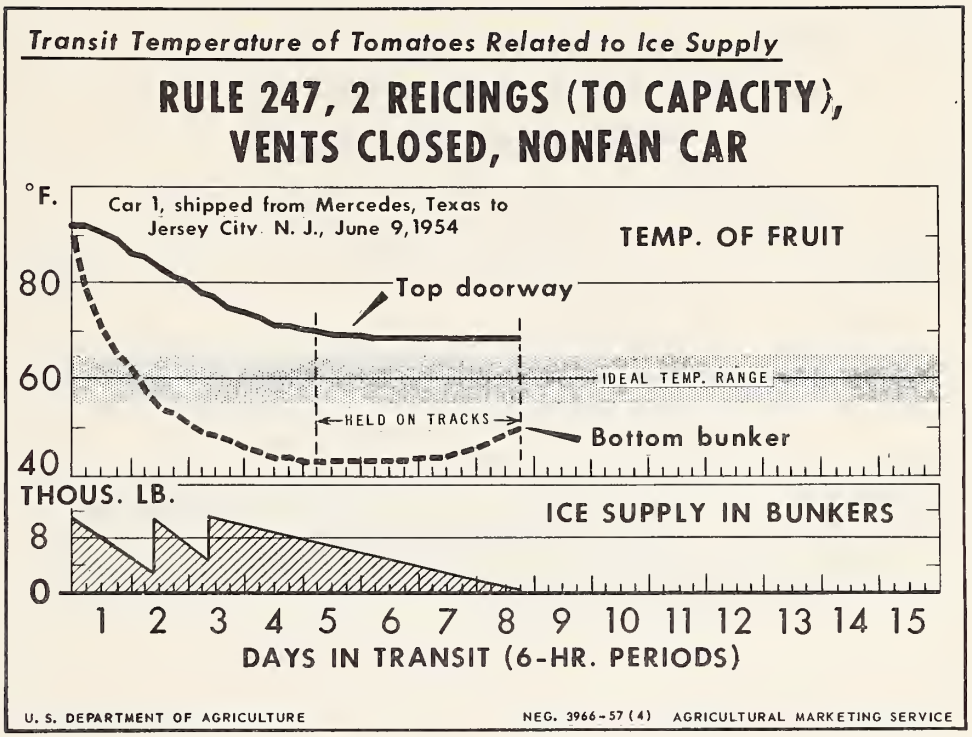


Figure 1

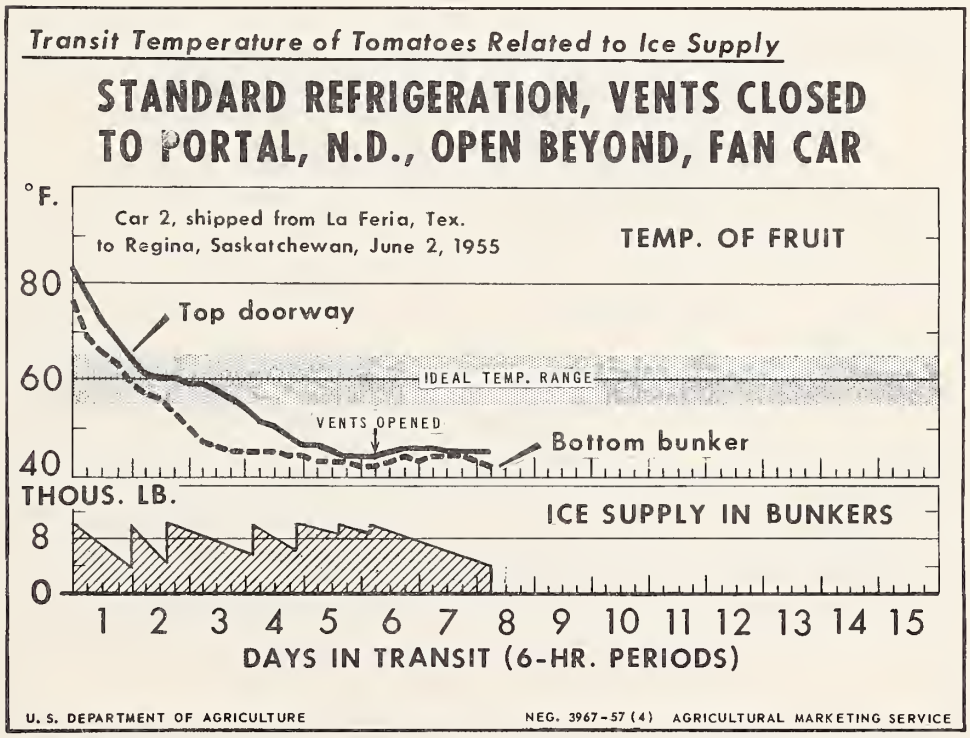


Figure 2

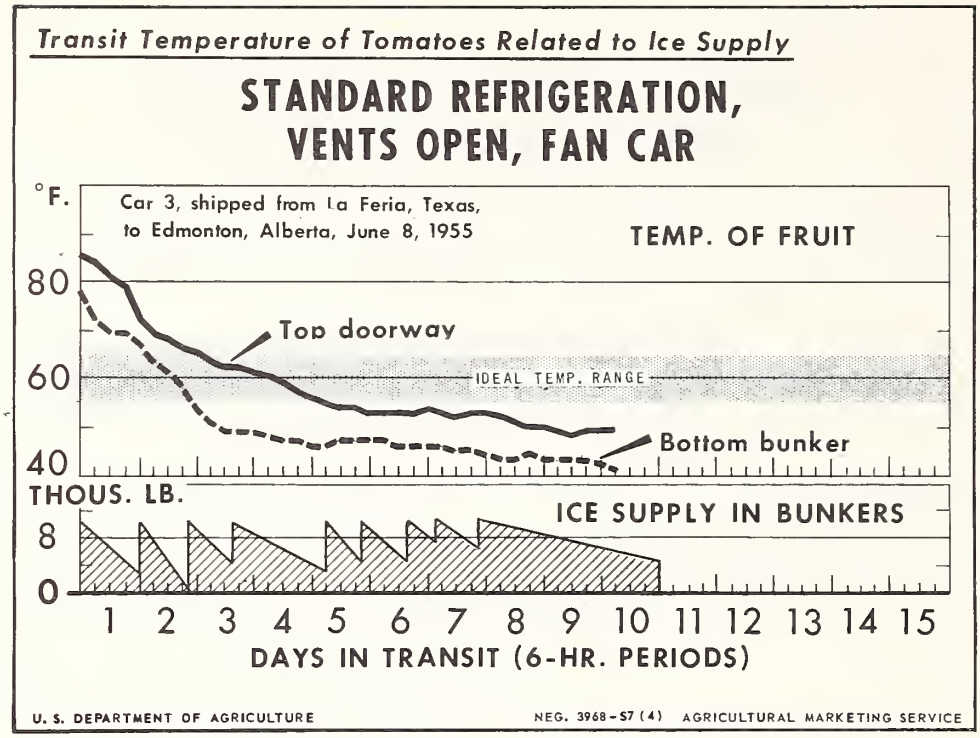


Figure 3

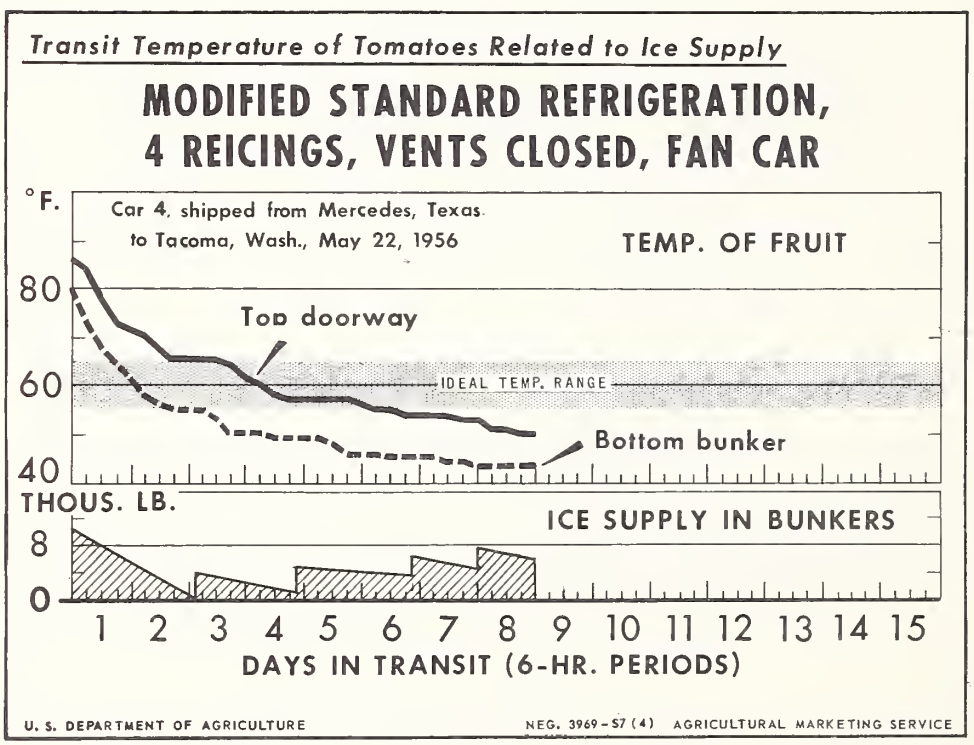


Figure 4

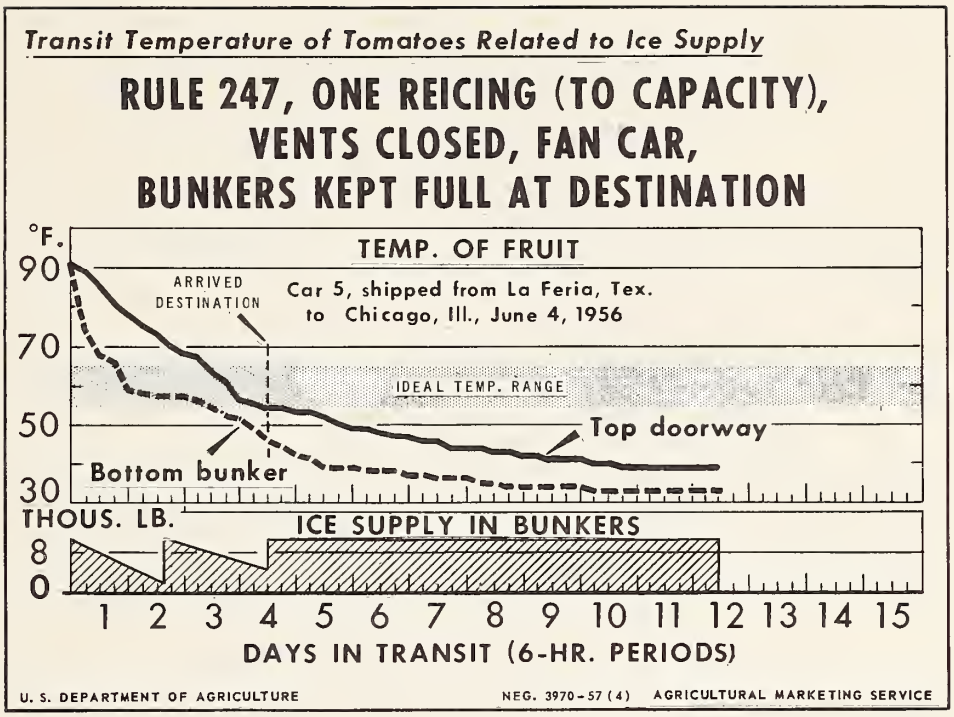


Figure 5

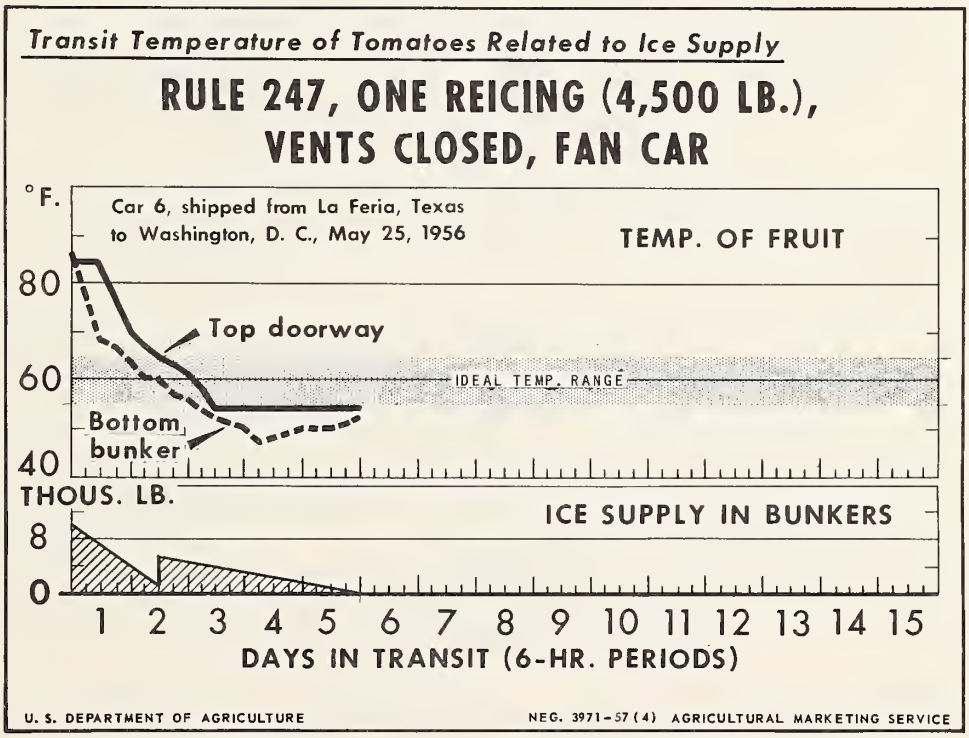


Figure 6

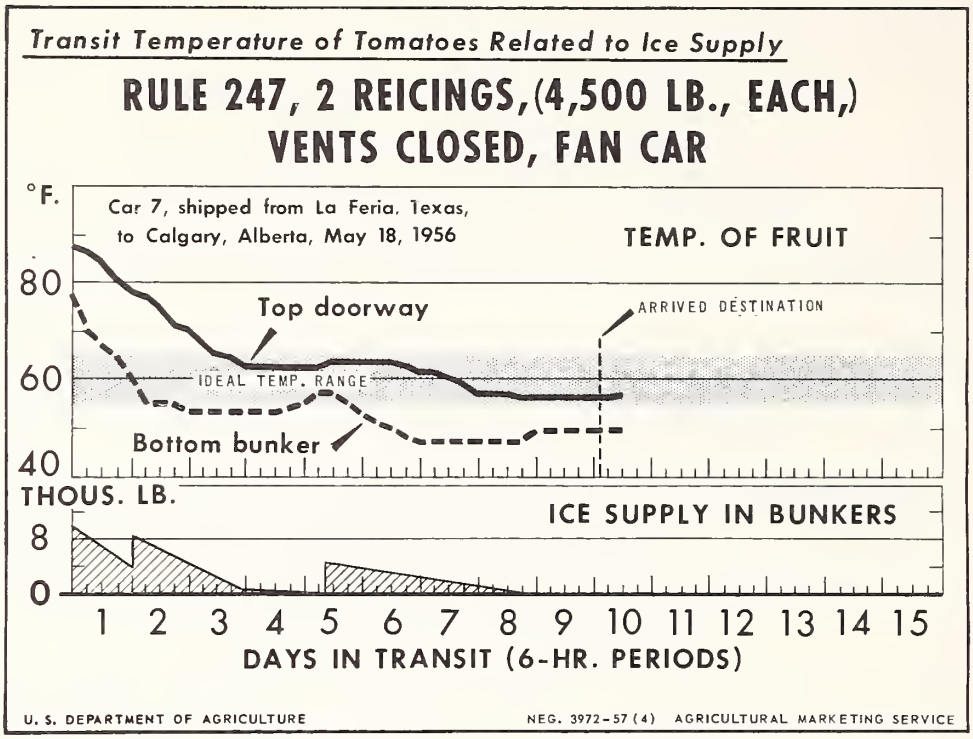


Figure 7

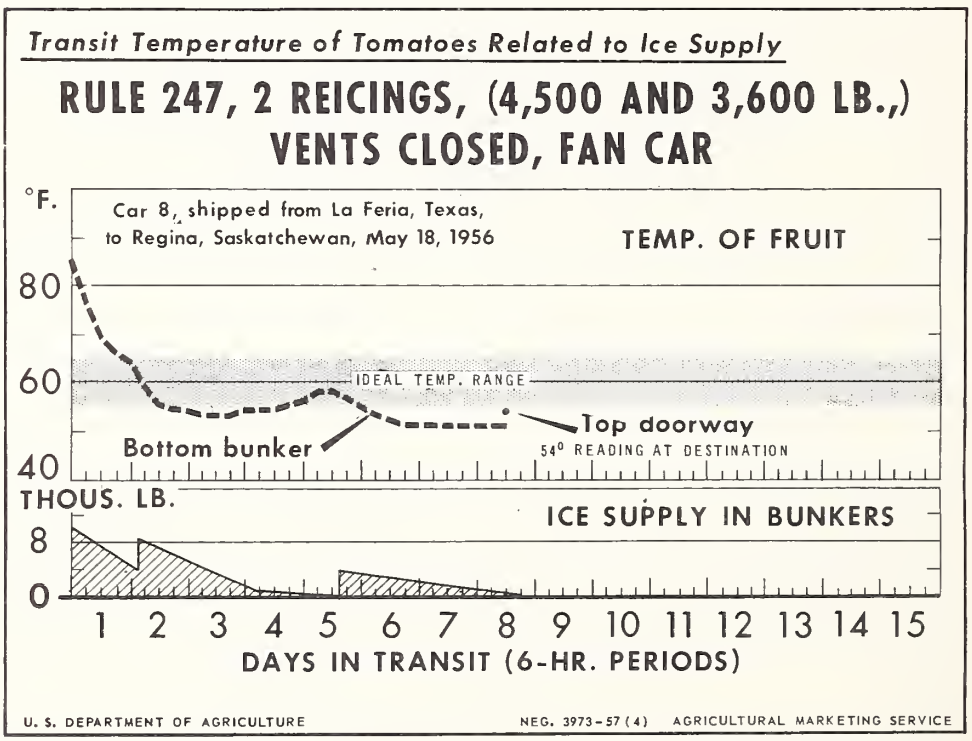


Figure 8